Silicone Additive Manufactured Indices Performed from a Virtual Diagnostic Waxing for Direct Composite Diastema Closure Combined with Resin Infiltration Technique on White Spot Lesions: A Case Report

Revilla-León, Marta ; Fountain, Joshua ; Piedra-Cascón, Wenceslao ; Zandinejad, Amirali ; Özcan, Mutlu

Abstract: The present article describes the resin infiltration technique to address white spots lesions presented on anterior and premolar teeth of a young patient after orthodontic treatment and the digital workflow for planning a diastema closure on the maxillary anterior teeth using facial photographs, an intraoral scanner, a facially driven diagnostic waxing using a dental computer-aided design (CAD) software, and 3-piece additive manufactured (AM) clear silicone indices. The virtual design of the silicone indices was completed using an open-source CAD software and included a flexible clear buccal piece, flexible clear lingual piece, and rigid clear custom tray. The unique 3-piece index design allows a horizontal path of insertion, controlled uniform thickness of the indices, flexible and rigid material properties combination, accurate translation of the diagnostic waxing into the patient´s mouth, and digital storage of the designs.

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Title

Silicone additive manufactured indices performed from a virtual diagnostic waxing for direct composite diastema closure combined with resin infiltration technique on white spot lesions: A case report.

Running Title

A 3-piece additively manufactured silicone index for direct composite diastema closure

Authors (First [Given name] Middle Last [Family name])

Marta Revilla-León DDS, MSD,[a] Joshua Fountain DDS,[b] Wenceslao Piedra-Cascón DDS, MS,[c] Amirali Zandinejad DDS, MSc,[d] and Mutlu Özcan DDS, DMD, PhD[e]

Institutions

[a]Assistant Professor and Assistant Program Director AEGD Residency, College of Dentistry, Texas A&M University, Dallas, Texas; Affiliate Faculty Graduate Prosthodontics, School of Dentistry, University of Washington, Seattle, WA: and researcher at Revilla Research Center, Madrid, Spain.

[b]Private Practice, Dallas, Texas.

[c]Affiliate Faculty Graduate in Esthetic Dentistry Program, Complutense University of Madrid, Spain and Researcher at Revilla Research Center, Madrid, Spain.

[d]Associate Professor and Program Director AEGD Residency, College of Dentistry, Texas A&M University, Dallas, Texas.

[e]Professor and Head, Dental Materials Unit, Center for Dental and Oral Medicine, University of Zürich, Switzerland.

Correspondence: Dr. Marta Revilla-León, Texas A&M University, Baylor College of Dentistry, 3302 Gaston Avenue, Room 713, Dallas, Texas, 75266-0677, United States. E-mail: revillaleon@tamu.edu

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Marta Revilla-León https://orcid.org/0000-0003-2854-1135

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ABSTRACT

The present article describes the resin infiltration technique to address white spots lesions presented on anterior and premolar teeth of a young patient after orthodontic treatment and the digital workflow for planning a diastema closure on the maxillary anterior teeth using facial photographs, an intraoral scanner, a facially driven diagnostic waxing using a dental computer-aided design (CAD) software, and 3-piece additive manufactured (AM) clear silicone indices. The virtual design of the silicone indices was completed using an open-source CAD software and included a flexible clear buccal piece, flexible clear lingual piece, and rigid clear custom tray. The unique 3-piece index design allows a horizontal path of insertion, controlled uniform thickness of the indices, flexible and rigid material properties combination, accurate translation of the diagnostic waxing into the patient´s mouth, and digital storage of the designs.

KEYWORDS: 3D Printing; Additive manufacturing technologies; Digital waxing; Resin Infiltration; Silicone index.

INTRODUCTION

The resin infiltration technique (RIT) has been described as an effective non-invasive treatment for white spot lesions (WSL) after orthodontic treatment.[1-3] The RIT is founded on hydrochloric acid erosion of the lesion surface and infiltration of a low-viscosity resin into the intercrystalline spaces of hypocalcified or demineralized enamel.[1] Dental literature has analyzed the penetration and color masking efficacy of the resin infiltration technique.[4-8] However, previous authors determined that the

RIT may be a reasonable treatment for masking of enamel whitish color alterations, subsequent from WSL and enamel developmental imperfections.[2-4]

A diagnostic waxing procedure is a fundamental treatment planning step for a successful restorative treatment.[9,10] A complete digital workflow for diagnostic and treatment planning procedures has been described using intraoral scanners (IOSs), dental and open-source computer-aided design (CAD) softwares, and additive manufacturing (AM) technologies.[11,12] Furthermore, the 3D virtual patient concept has been developed with the integration of different digital technologies.[13]

AM procedures manufacture virtual designs through a layer-by-layer building procedure.[14] The accuracy of 3D printers depends on multiple features namely data processing, technology employed, printer calibration, ambient temperature where the 3D printer is located, power of the light source, platform positioning, supportive structures, material properties, slicing software, resin color, geometry of the object, photo-initiators, wavelength power, and post-processing procedures.[15-19]

The employment of a silicone index has been reported to translate the digital design to the patient´s mouth through a diagnostic trial restoration.[11,12] Furthermore, vat-polymerization AM technologies have been previously described to fabricate clear silicone indexes to perform diagnostic trial restorations from a diagnostic design,[12] or to prepare interim dental restorations.[12,20] However, in the present case report, a unique 3-piece AM silicone index was developed. The design of the clear silicone index involved two flexible indices, the buccal and lingual indices, wih a rigid clear custom tray.

The present article describes the a resin infiltration technique to address the white spots presented on the maxillary and mandibular teeth of a young patient after orthodontic treatment and the digital workflow for planning a diastema closure on the maxillary anterior teeth using facial photographs, an IOS, a dental and open-source CAD software, and AM technologies.

CLINICAL REPORT

A 17-year-old patient was referred after his orthodontic treatment was completed for restorative closure of the interproximal space between his maxillary central incisors. The anamnesis indicated

healthy general condition. Extraoral and dento-facial evaluation revealed medium lip line, convex smile line, and 2 mm of the maxillary tooth display at rest position. Intraoral and radiographic examination showed generalized gingivitis, the gingival margins of both maxillary central incisors located in a more apical position in relation to the maxillary lateral incisors and canines, multiple white spot lesions non-cavitated on the facial surface of the maxillary and mandibular teeth, the maxillary left central incisor presented a class-IV composite restoration, and diastema between maxillary central incisors (Figs 1AB).

A facially driven virtual diagnostic waxing was performed to evaluate the esthetic restorative outcome. Extraoral and intraoral photographic documentation was obtained using a digital camera, and an intraoral digital scan was performed using relative isolation (OptraGate; Ivoclar Vivadent, Schaan, Liechtenstein) and an IOS (TRIOS 3 Color; 3Shape, Copenhagen, Denmark) at ambient light scanning conditions of 1003 lux following the scanning protocol recommended by the manufacturer. A dental CAD software (Dental System; 3Shape, Copenhagen, Denmark) was selected to elaborate an additive diagnostic waxing with the objective of closing the interproximal diastema between the maxillary central incisors. It was desired to simultaneously create both maxillary central incisors with the same width, make the maxillary dental midline parallel with the facial midline, and make the maxillary dental midline coincident with the facial midline if possible (Fig 2).

The diagnostic waxing cast file was used to design the 3-piece AM index using an open-source CAD software (Blender, version 2.77a; Blender Foundation, Amsterdam, Netherlands). The three pieces included a flexible clear buccal piece, flexible clear lingual piece, and rigid clear custom tray, designed according to the next steps:

A. The lingual index outline was marked using the “Splints” tool. The lingual index was fashioned with a uniform thickness of 2.5 mm. Three indentations were created on the lingual surface of the lingual index for the posterior location of the buccal index using the “Cone” tool of the “Create” menu of the software.

B. Step A was repeated for the design of a buccal index with a thickness of 2.5 mm. The buccal index covered the buccal, incisal and inciso-lingual surfaces of the involved teeth such that the buccal index interlocked with the lingual index (Fig 3A).

C. The two indices designed in the steps A and B and the diagnostic waxing maxillary cast were duplicated with a thickness of 4 mm. The "difference" Boolean tool was selected to subtract the 4-mm duplicated index from the 2 indices designed in steps A to B. This procedure resulted in the creation of a custom tray with a 2.5 mm thickness that covered the buccal and lingual indices (Fig 3B).

Three files were obtained from the digital design of the 3-piece index: the buccal (STL_1) and the lingual indices (STL_2) and the custom tray (STL_3) design. The STL_1 and STL_2 files were selected to fabricate the silicone indices using a direct light processing (DLP) printer (RapidShape D30 II; RapidShape, Heimsheim, Germany) with a 25-μm layer thickness of flexible clear resin (Nexdent Ortho IBT; Nexdent, Soesterberg, Netherlands) (Fig 4A). The same DLP printer was used with the STL_3 file to fabricate the custom tray with a 25-μm layer thickness of clear rigid resin (Nexdent Ortho Clear; Nexdent) (Fig 4B).

The silicone indices were used to prepare diagnostic trial restorations on the maxillary central incisors using a self-polymerizing bis-acryl provisional resin material (Protemp Plus temporization material, A2 shade; 3M ESPE, Minnesota, USA). The diagnostic trial restoration did not require any modification.

The treatment plan options and treatment sequence to treat the WSL were discussed, and the patient's consent was obtained after understanding the known esthetic limitations of the RIT. Resin infiltration technique was selected to address the WSL on the facial surfaces of right maxillary canine, right and left maxillary lateral incisor, left first maxillary premolar, left first and second mandibular premolars, and all mandibular anterior teeth. Moreover, to close the diastema between the maxillary

central incisors, direct composite restorations were chosen due to the conservative restorative characteristics.

Before any treatment was performed, a prophylaxis was performed and hygiene instructions were reinforced with the patient. Re-evaluation visits were performed until the gingival appeared pink and healthy without bleeding on probing.

Resin infiltration technique (Icon; DMG America, New Jersey, USA) was accomplished on each affected tooth individually under complete isolation (Fig 5A) following the manufacturer´s recommendations. Each white spot lesion was etched 2 times with hydrochloric acid (Icon-Etch; DMG America, New Jersey, USA) for 2 minutes each. If the white spot lesion was still noticeable after the second etch cycle, a third etch cycle was performed for another 2 minutes (Fig 5B). After completing the etching protocol, the tooth surface was rinsed for 30 seconds and dried. A coat of 99% alcohol (Icon-Dry; DMG America, New Jersey, USA) was applied and let sit for 30 seconds and then dried (Fig 5C). A generous coat of methacrylate-based resin matrix (Icon-Resin; DMG America, New Jersey, USA) was applied and allowed to sit for 3 minutes before light-polymerizing with a dental light curing machine (Elipar DeepCure-S Led curing light; 3M ESPE, Minnesota, USA) for 40 seconds, after which another layer of the same resin was generously applied and allowed to sit for 1 minute before light-polymerizing for 40 seconds again (Fig 5D). Then, the complete isolation was removed and the final surface finish was produced using polishing discs (Sof-Lex XT Extra thin; 3M ESPE, Minnesota, USA) (Fig 6A).

The diastema presented between the maxillary central incisors was addressed with direct composite resin restorations using a layering technique. The lingual index (Fig 6B) was selected to perform the placement of the first layer of the composite resin restoration (WE Filtek Supreme XTE; 3M ESPE, Minnesota, USA), which was also placed to emulate the incisal halo present on the patient´s natural dentition. The second layer applied was the dentin composite layer, (A2 and A1 Premise Universal Nanofilled composite; Kerr, Massachusetts, USA) emulating the dentin mamelons, and a small blue translucent (Translucent Blue Filtek Supreme XTE; 3M ESPE, Minnesota, USA)

effect was obtained between the composite dentine mamelons created. A white stain (White Kolor+Plus; Kerr, Massachusetts, USA) characterization was applied on the superficial layer of the dentin composite to reproduce the marked white enamel on the facial incisal third of the patient´s natural dentition. To complete the composite restoration, a layer of enamel composite resin (Clear Premise Universal Nanofilled composite; Kerr, Massachusetts, USA) was applied using the buccal silicone index to guide the final contours of the restorations (Fig 6C). Surface finishing was accomplished with polishing discs (Sof-Lex XT Extra thin; 3M ESPE, Minnesota, USA) and a polishing paste (Enamelize polishing paste; Cosmedent,Chicago, USA) combined with a different set of polishing discs (Flexibuff; Cosmedent, Chicago, USA). The occlusal contacts were checked and adjusted as needed.

One week after the composite restorations were performed, shade matching and composite restoration integration was performed. Patient was satisfied with the esthetic outcome of his treatment. Final photographs were obtained and patient was introduced into a one-year recall protocol (Figs 7AB).

DISCUSSION

The case report presented described a complete digital workflow, but since the most conservative treatment was demanded by the patient, direct composite resin restorations were selected to close the interproximal space between his maxillary central incisors. However, if another restorative treatment was selected, such as a ceramic veneer, the clinical intervention could have been performed digitally with a intraoral scan of the tooth preparation and using the diagnostic trial restoration as a guide for the design of the restoration planned.

Direct composite restoration was selected due to the conservative characteristics, predictable bonding due to the presence of enamel, and easier technique compared to indirect restorations. Previous authors have analyzed the longevity of direct composite restorations on anterior teeth reporting a good long-term (follow-up 3+ years) clinical performance reporting annual failure rates fluctuating from 0 to 4.1%.[21] Composite resin restorations performed on the anterior dentition

presents different clinical performance compared with composite restorations completed on the posterior teeth showing lower incidence of secondary dental caries and higher number restorations being substituted for other causes such as poor esthetic look.[21]

The incorporation of AM silicone indices provides several advantages namely the control of the extension and thickness of the silicone indices, elimination of the need to manufacture the diagnostic casts, and elimination of the need to perform a conventional silicone index using the diagnostic AM cast which may accumulate more dimensional errors. Furthermore, the unique proposal of the AM silicone indices into 2 pieces namely buccal and lingual provides an important improvement by changing from the vertical path of insertion to a horizontal path of insertion. The digital design permits the easy interlocking of both pieces together when seated on the teeth, and the customized rigid tray minimizes feasible distortion of the flexible buccal and lingual indices during handling. Moreover, the lingual index was selected to build up the lingual layer of the direct composite resin restorations, translating the shape, size, and position of the virtually designed restoration. The clear characteristics of the AM resin chosen permits for light-polymerization of composite resin material through the indices.

Moreover, an open-source software was selected to design the silicone indices providing a limitless application for virtual design. Dental software is specifically developed for dental professionals and provides restricted design options with a more intuitive tools for dental designs when compared with open-source CAD software, and this dental-specific CAD software was selected to perform the digital waxing procedures of both maxillary central incisors.

The level of color masking achieved using the resin infiltration technique was different among the different teeth treated. The maxillary teeth and mandibular canines treated obtained an acceptable color masking of the enamel whitish discolorations, however, the mandibular incisors obtained a less apparent level of color masking (Fig 6A).

SUMMARY

The current report presents a complete digital workflow using full-face patient´s images, intraoral scanner (IOS), dental and open-source computer-aided design (CAD) softwares, and additive manufacturing (AM) technologies to assist the restorations performed on the maxillary central incisors. A digital diagnostic waxing was performed with dental CAD software and used to additively manufacture a 3-piece silicone index design which include a labial and lingual flexible silicone indices with a rigid custom tray. This unique 3-piece AM clear silicone index provides an important improvement by changing the path of insertion from vertical to horizontal, translate accurately the size and shape of the virtually planned restoration, and permits for light-curing of material through the silicone index.

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Figure Legends

Figures 1AB. A, Lower third frontal smile of the patient. B, Frontal view of the maxillary and mandibular arches in maximum intercuspation.

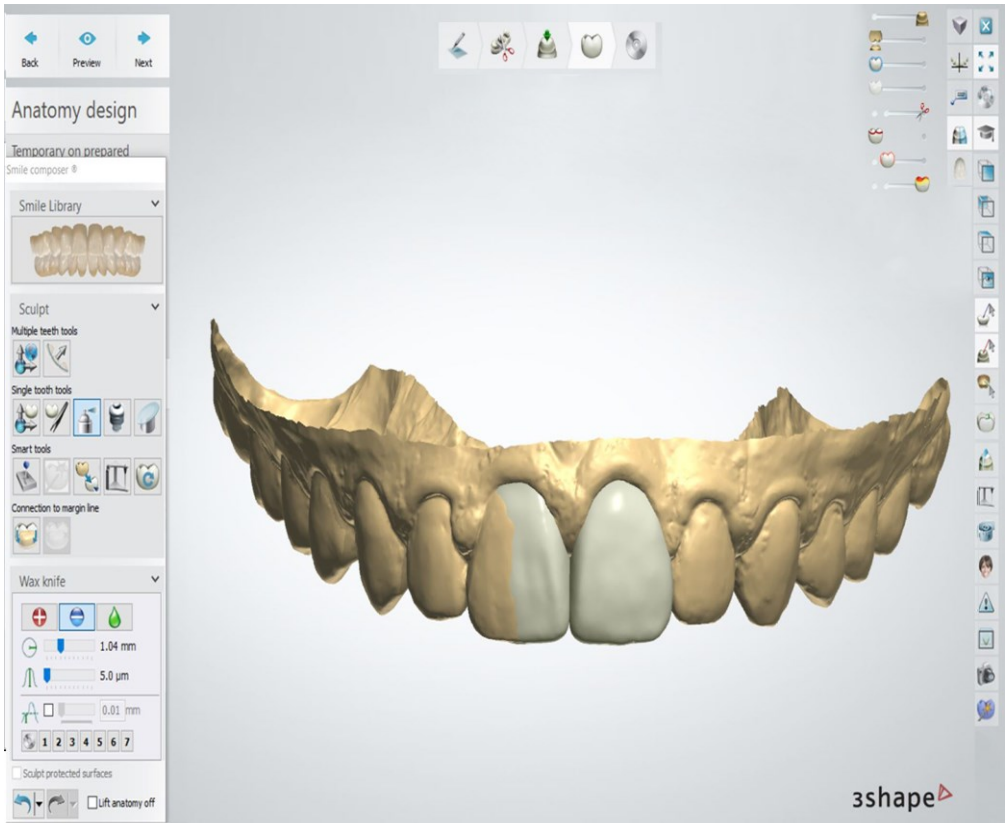
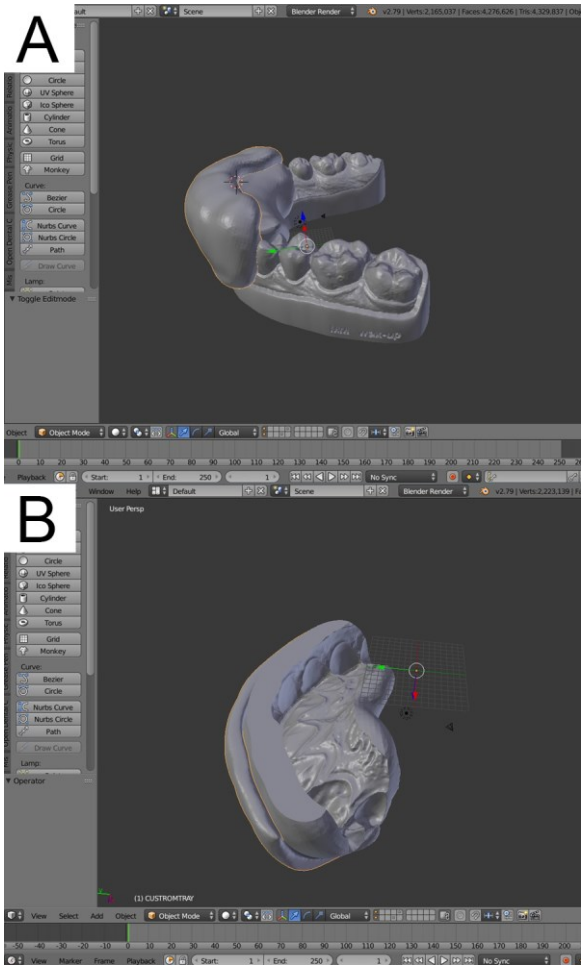
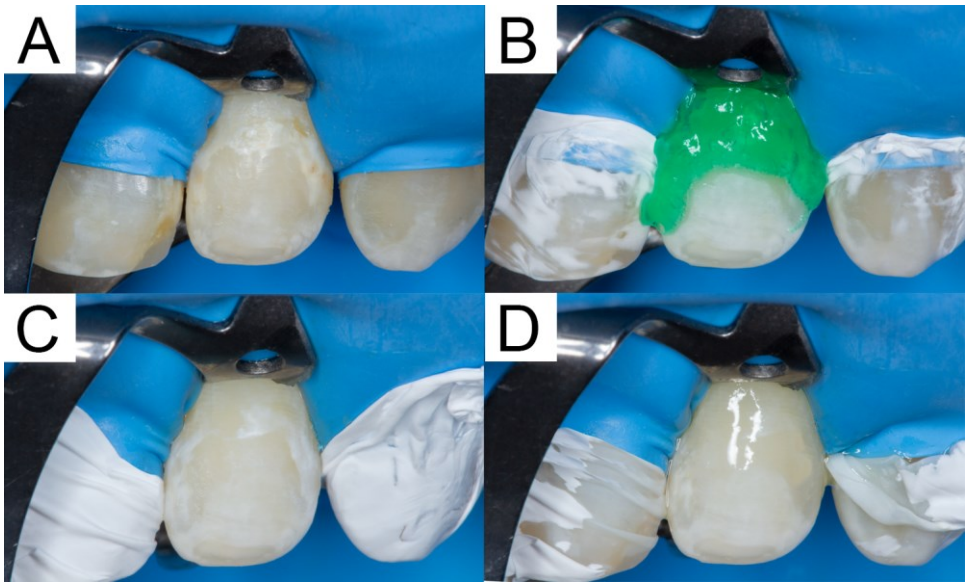


Figure 2. Additive diagnostic waxing procedures were performed using the teeth library and morphing tools of the dental CAD software (Dental System; 3Shape, Copenhagen, Denmark).



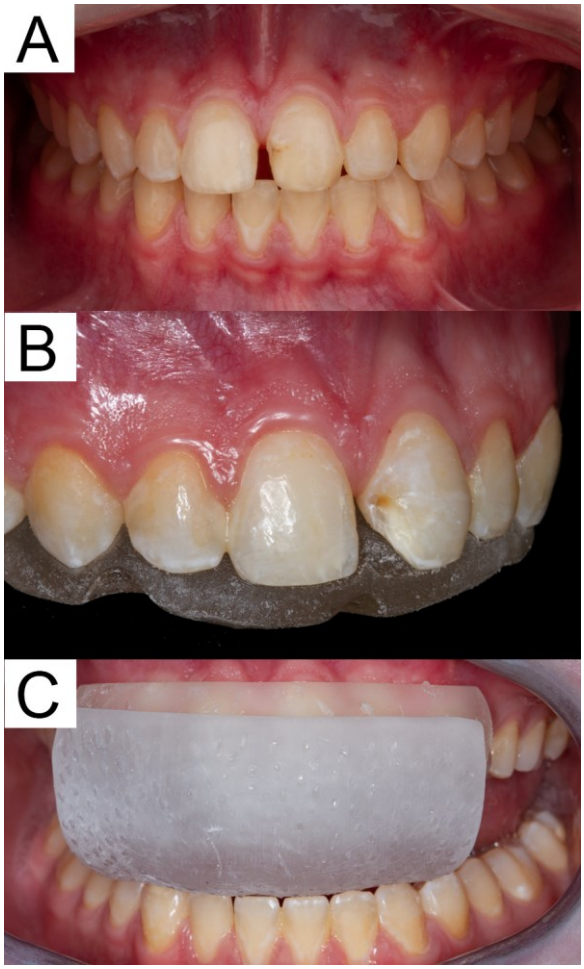
Figures 3AB. Digital design of 3-pieces silicone indices using an open-source CAD software (Blender, version 2.77a; Blender Foundation, Amsterdam, Netherlands). A, The labial index covered the labial, incisal and inciso-lingual surfaces of the involved teeth such that the labial index interlocked with the lingual index. B, The 2-piece AM silicone index, labial and palatal, were designed and adapted into a clear rigid AM custom tray.

Figures 4AB. Additive manufactured silicone indices. A, Labial and lingual flexible and clear silicone indices interlocked. B, Rigid and clear custom tray which covered the labial and lingual indices.



Figures 5A-D. Resin infiltration technique (Icon; DMG America, New Jersey, USA) performed on the white lesions presented on the buccal surface of the maxillary left lateral incisor. A, Complete isolation was obtained using a rubber dam, clamp, and metal frame. B, Each white spot lesion was etched 2 times with hydrochloric acid (Icon-Etch; DMG America, New Jersey, USA) for 2 minutes each. C, A coat of 99% alcohol (Icon-Dry; DMG America, New Jersey, USA) was applied and let sit

for 30 seconds and then dried with water-free air syringe. D, A generous coat of methacrylate-based resin matrix (Icon-Resin; DMG America, New Jersey, USA) was applied and allowed to sit for 3 minutes before light-polymerizing.



Figures 6A-C. A, Frontal maxillary and mandibular arches before the composite restorations were accomplished. B, The direct composite restorations were performed lingual AM silicone index. C, Labial index and custom tray were used to obtain the final contours of the composite restorations.

Figures 7AB. A, Lower third frontal smile of the patient. B, Frontal view of the maxillary and mandibular arches in maximum intercuspation after the closure of the diastema between the maxillary central incisors.